California Natural Gas Storage Deliverability Options

Andy Hammerschmidt
Program Manager/GTI

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California Natural Gas Storage Deliverability Options

Project Partners

Southern California Gas Company

Pacific Gas and Electric Company

- Operational Insight
- Infrastructure Support
- Gas Storage Utilization

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California Natural Gas Storage Deliverability Options

Task Objective

"How can natural gas storage be utilized to provide cost effective service to California consumers?"

- Impact of demand trends on gas storage and its ability to adapt in meeting it
- **Determine feasibility of alternative gas storage technologies**
- LNG impacts (physical and economical) on existing gas storage infrastructure
- Review regulatory policies on LNG integration

California Natural Gas Storage Deliverability Options

Project Actions

- Analyze impacts of Task 2 – Demand trending
- **Perform broad search on natural gas storage technologies – technology transfer, technology consortiums, etc…**
- Effects of LNG Interchangeability on gas storage infrastructure

California Natural Gas Storage Deliverability Options

Project Approach

- Focus on supplementing traditional gas storage with point source or distributive energy – minimize infrastructure limitations
  - Cold Compressed Natural Gas
  - Hydrate Storage
  - Compressed Natural Gas
  - Small Scale LNG
  - Adsorbent Technologies

California Natural Gas Storage Deliverability Options

Project Approach

- Focus on enhancing traditional underground gas storage deliverability/capacity
  - Remedial Techniques
  - Base/Working Gas Ratios

- LNG effects on gas storage infrastructure focusing on interchangeability issues

Alternative Technology Review

Cold Compressed Natural Gas (CCNG)

Technology Overview

CCNG is a denser and “cleaner” version of NG. It is stored at refrigerated temperatures and under pressure. Steady state storage conditions of CCNG would include temperatures of –150°F and colder and pressures of 700 psig and greater. Due to its cryogenic state, the chemical composition of CCNG needs to be slightly different than “pipeline-quality” NG in order to avoid the forming of liquid products that would act like “slush” and “ice”.

Alternative Technology Review

Cold Compressed Natural Gas (CCNG)

Technology Parameters

	CNG	CCNG	LNG
Pressure (Psig)	2,700 +	700 - 1,500	50
Temperature (F)	+ 110	- 150	- 260
Pounds Per Cu. Ft.	8.3	23	26.5
Density Relative to LNG	31%	86%	100%
KWH-to-Density Ratio	0.57	0.38	0.57

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Alternative Technology Review

Cold Compressed Natural Gas (CCNG)

Technology Applications

- Site Specific Storage
- Pipeline
- Transportation of LNG Inland
- Below Ground
  - Lined Rock Cavern
  - Very low cushion gas requirements (2%-5%)

Alternative Technology Review

Cold Compressed Natural Gas (CCNG)

Technology Benefits

- At 86% of the density of LNG, CCNG can be stored in smaller facilities than required for warm CNG
- At -150 F, it is much “warmer” than -260 F LNG, allowing for potential storage of CCNG lined rock caverns with controls
- Requires the least energy input of all forms of NG, relative to the achieved density
- Can be maintained in a single “phase”
- Can be “pumped”(like a liquid) to any pressure, without the need for large compressors
- Can be transported in small-diameter / large-volume CCNG pipelines over long distances
- CCNG’s “cold” energy can be recovered, stored and re-used

Alternative Technology Review

Natural Gas Hydrate Storage

Technology Overview

Gas hydrates (clathrates) are ice-like crystalline compounds that form under low temperature and elevated pressure conditions. Within the gas-hydrate lattice, water molecules form a network of hydrogen-bonded cage-like structures enclosing the guest molecules that generally comprise low-molecular-diameter gases [e.g., methane, ethane, propane, or carbon dioxide (CO[2])].

Alternative Technology Review

Natural Gas Hydrate Storage

Technology Application

- Site Specific Storage
- Above Ground
- Below Ground
  - Reservoir w/ promoter
  - Lined Rock Cavern

Alternative Technology Review

Natural Gas Hydrate Storage

Technology Benefits

- Storage Density/Capacity – Smaller Infrastructure Footprint
- Relatively low operating pressures – Reduction of pressure losses due to narrow operating requirements
- Lower base gas requirements than traditional compressed natural gas storage systems

Alternative Technology Review

Compressed Natural Gas

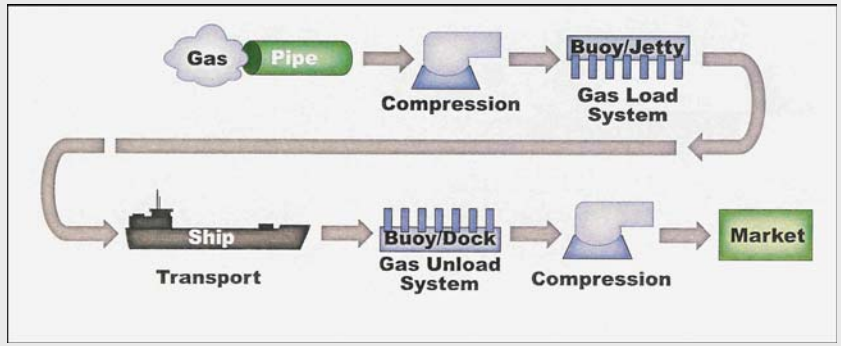
Technology Overview

CNG maintains natural gas in a gaseous state at pressures between 1200 and 3600 psi. CNG systems investigated include site specific, land based applications typically comprised of long, large-diameter or coils of small diamter pipes contained within an insulated structure integrated into a housing. It combines optimal storage efficiency, ability to transport CNG, and significantly lower compression requirements to increase vessel capacity.

Alternative Technology Review

Compressed Natural Gas

Technology Parameters



Storage Capacity	Scalable (20 MMcf – 1 Bcf)
High Deliverability	5 MMcf/d – 500 MMcf/d
Flexibility (Cyclic Storage)	52 to 365 cycles – varies by volume
Storage Pressure	1500 – 2000 psi
Withdrawal Pressure	300 – 500 psi (regulated)

Alternative Technology Review

Compressed Natural Gas

Technology Benefits/Capabilities

- Injection capabilities during off-peak hours within peak season
- Instant supply for peak shaving purposes
- Insulates consumer against service interruptions and pressure reductions
- Create arbitrage value in daily trading
- Ability to augment pipeline capacity/balancing

Alternative Technology Review

Small Scale LNG

Technology Overview

LNG is the result of cooling natural gas to approximately 260 degrees below zero. This cooling both liquefies and condenses the natural gas so that it occupies a space approximately 600 times smaller than when in its gaseous state.

Standardized refrigeration compressor and heat transfer components allow for easy scalability of the system to match various LNG market needs. The use of standardized components results in a comparably low first-cost position for this technology compared to scaling down conventional liquefaction systems.

Alternative Technology Review

Small Scale LNG

Technology Applications

- Portable
- On location LNG, small footprint (240 ft^2)
- NGV fueling stations
- Satellite installations for communities without service
- 5,000 – 30,000 gal/day target

*10,000 gallons per day experimental technology demonstration plant located in Sacramento and owned by Pacific Gas & Electric

Alternative Technology Review

Small Scale LNG

Technology Benefits/Capabilities

- Local production of LNG at location of use
- Eliminate transportation costs
- Satellite installations for continuous service
- Lower costs with technology advancements ($450,000)
- Peak Shaving

**System developed by GTI/DOE*

Commercialized by Linde BOC

Alternative Technology Review

Adsorbed Natural Gas

Technology Overview

With ANG technology natural gas is "stored" in a special micro-porous material placed inside the pressure vessel. This material acts as a sponge to adsorb natural gas. The vessel containing adsorbent can store much more NG than regular CNG vessel at the same pressure level. For example, in order to store the same gas quantity as CNG vessels at 2900 psi, ANG vessel needs storage pressure of approximately 380 psi. The gas adsorption process is accompanied by heating of the adsorbent while de-sorption (release) causes the system's freezing. Fast vessel filling and release requires control of thermo-processes.

Alternative Technology Review

Adsorbent Technologies

Technology Applications

- Portable - Transportation
- On location, significant reduction in tank size
- NGV fuel
- Below ground installations possible

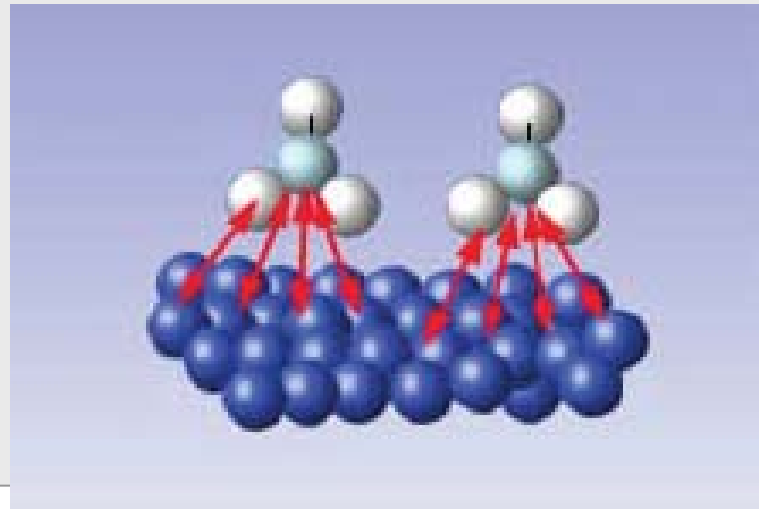
**Storage Tank selected for experimental conversion to ANG*

Alternative Technology Review

Adsorbent Technologies

Technology Benefits/Capabilities

- Implementation at the point of need and reduced dependence on transmission or distribution systems
- 30-fold volumetric enhancement can be achieved
- Satellite installations for continuous service
- Peak Shaving
- Line Pack Alternative



Thank You!

For more information:

Andy Hammerschmidt
T: (847) 768-0686
andrew.hammerschmidt@gastechnology.org

www.gastechnology.org